AD-A177 691 POPULATION REGULATION OF MANSONIA MOSQUITOES ON WATER LETTUCE (PISTIA STRATIOTES L)(U) FLORIDA MEDICAL ENTOMOLOGY LAB VERO BEACH L P LOUNIBOS JUL 86 1/1

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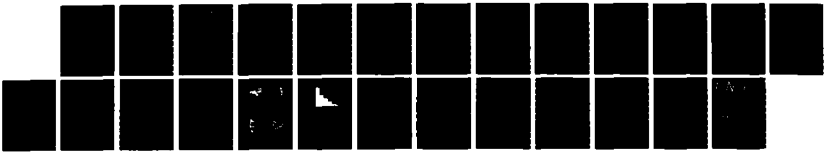

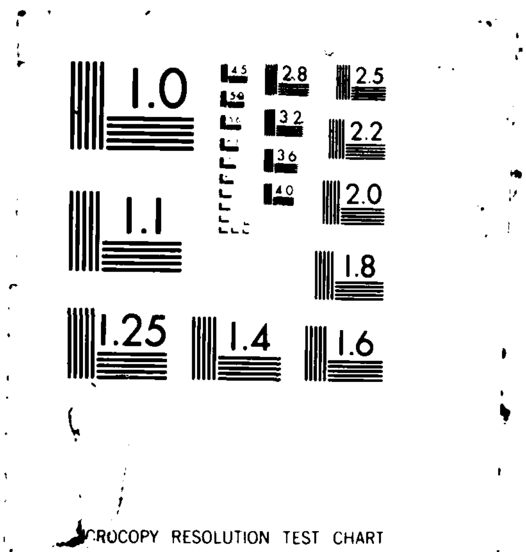
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Population Regulation of Mansonia Mosquitoes on Water Lettuce (Pistia stratiotes L.)

Annual Report

L. P. Lounibos

July, 1986

Supported by

U.S ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701-5012

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Florida Medical Entomology Laboratory
University of Florida
Vero Beach, Florida 32962

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Two sites in St. Lucie County, Florida were chosen to compare population regulation in areas of high and low Mansonia abundances. Adult and egg stages of Mansonia were monitored biweekly, and larval stages, host plant (Pistia) characters, and abundances of other aquatic organisms were censused monthly. Adult Mansonia production at Chinese Farm was approximately tenfold that at HWY 614 in spite of similar densities of immatures. Pistia and Mansonia numbers were reduced by cold winter temperatures, and the first signs of host

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plant recovery were not observed until June. Water quality measures at the two sites ~~were similar~~ except for dramatic differences in total phosphates and small differences in DO and pH. Mansonia dyari oviposited more frequently on the upper than on the under surfaces of Pistia leaves, apparently in evolutionary adaptation to this host plant. Larval Odonata were the most common insects recovered on Pistia roots, and some evidence of predation on Mansonia is presented.

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Population Regulation of *Mansonia* Mosquitoes on Water Lettuce (*Pistia stratiotes* L.)

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ABSTRACT

The current report describes the results of the first year of study of factors regulating populations of _Mansonia dyari_, a pest mosquito and potential disease vector in south Florida. On the basis of preliminary surveys of six sites, two were chosen with respective high and low populations of _Mansonia_.

Water lettuce (_Pistia_) plants were monitored monthly at both Chinese Farm (CF) and HWY 614. Cold temperatures produced major plant mortality in January. Regrowth was observed at CF in March, but _Pistia_ biomass did not increase until June.

In the early months of the study, _Mansonia_ egg and larval densities were comparable, but adult production was tenfold higher at CF. As temperatures decreased late in the fall, _Mansonia_ egg and adult production declined at both sites, albeit more rapidly at HWY 614. _Mansonia_ larvae were still abundant at CF in January, but thereafter rare through June. Recovery of the mosquito population from winter cold was exceedingly slow.

Water quality measures at the two sites were similar, although dissolved oxygen and total phosphates were higher at CF. A computer-based weather data logging system was constructed and established in the field at CF.

All aquatic invertebrates and fish associated with _Mansonia_ in monthly _Pistia_ collections were counted and identified. Of these, larval Odonata were demonstrated as preying upon _Mansonia_ larvae. All aerial insects captured in emergence traps were counted and identified.

Egg mass surveys revealed that _M. dyari_ oviposited on both the under and upper surfaces of _Pistia_ leaves, an ability heretofore unknown among _Mansonia_. The related _M. titillans_ was capable of only under-surface oviposition, and the behavior of _M. dyari_ is proposed to be an evolutionary adaptation to its _Pistia_ host plant. _Mansonia_ egg masses were shown to be aggregated on _Pistia_ leaves.

FOREWORD

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I. Statement of Problems

The research supported by this contract is based on the hypothesis that the production of *Mansonia* mosquitoes is related to the abundance and growth of its host plant and the chemical and physical state of the aquatic milieu supporting these plants. Important biological events limiting *Mansonia* production may include specialized aquatic predators, an insufficiency of larval food, and suitable oviposition sites. Detachment of *Mansonia* larvae from their host plants for dispersal may be an event exploitable for mosquito control.

II. Background

Mansonia mosquitoes are of special interest because of their pest status and involvement in cycles of disease transmission. The obligate association of immature *Mansonia* with the roots of aquatic plants has retarded the development of methods of sampling, rearing, and *Mansonia* control. In Florida, water lettuce (*Pistia stratiotes*) is the primary host plant for *Mansonia dyari*. To date no studies have attempted to associate growth and development of *Pistia* with attached *Mansonia* and other aquatic invertebrates. Predators are abundant in *Pistia* roots, and these may affect *Mansonia* levels. Variations in water chemistry at *Pistia* sites may affect *Mansonia* abundances.

III. Rationale

The research undertaken is based on the premise that appropriate observations and experiments may reveal certain cause-effect relationships between the abundance of *Mansonia dyari*, its *Pistia* habitat, and co-occurring aquatic organisms.

IV. Experimental Methods

Sampling of Pistia *quadrats*

A PVC framework 5 X 2 m was placed over *Pistia* at the two study sites for monthly measurements of plant growth. The frames were anchored to prevent sinking or drifting. The area within each frame was divided into 96 quadrats 30 X 30 cm, each quadrat assigned a number. On sampling dates, 5 quadrats were chosen from a random numbers table, and a plant sampler lowered to cut and remove organic contents. The sampler was a 30 X 30 X 100 cm tall aluminum box with cutting teeth and a hinged door for trapping the sample.

Quadrat samples were brought in buckets to the laboratory where the total numbers of *Pistia* plants, leaves, and flowers were counted. Leaves and roots were dried in an oven at 80°C for 48 hours and these samples weighed. Leaf areas were measured with an area meter.

Aquatic invertebrates were shaken from Pistia roots, sorted, counted, and classified while still alive. Clean tap water was maintained for 24 to 48 hours over muck or debris remaining from quadrat samples to recover additional invertebrates which surfaced for air. Growth stages of selected invertebrates (e.g. mosquitoes and Odonata) were measured by instar or body length. Fish captured in quadrat samples were also counted and identified. Specimens fixed in ethanol or formalin were mailed to taxonomists for identifications.

Emergence trapping

Two pyramidal emergence traps, each 1 X 1 m, were maintained over Pistia at the two sites. Aerial adults were captured on a 20 X 20 cm plate which contained an adhesive and rested horizontally at the apex of the pyramid. Plates were changed weekly, and traps re-positioned every 6 to 8 weeks. Traps were operated continuously until November when sampling was performed only on alternate weeks.

In the laboratory, insects were removed from the adhesive with a solvent, sorted, counted, and identified. Representatives of each morphotype were preserved in alcohol or on pins and shipped to specialists for generic and specific identifications.

Egg sampling

The abundance and distribution of Mansonia egg masses were studied by examining 50-100 Pistia leaves at biweekly intervals at each site. Only leaves greater than 10 cm long and partly immersed in water were examined, except after January 1986 when only smaller leaves were available.

Intact leaves with eggs were brought to the laboratory where the positions of masses on the leaf were measured. Eggs were allowed to hatch to determine viability and specific identities by head capsule widths.

Water quality measurements

Chemical properties of water were measured monthly at the two sites. Dissolved oxygen, pH and water temperature were measured from surface water. For other determinations, 300 ml of water were carefully decanted into a plastic bottle, brought to the laboratory, and maintained at 4°C until analysis. Nitrites, nitrates, ammonia, ortho-phosphate, and total phosphate were measured with Hach test kits.

Weather data logging

Beginning in April, weather data were collected continuously on a computer-based logging system (Appendix I). Rainfall, wind speed and direction, and solar radiation were fed, after analog to digital conversion, into a mini-computer housed in a waterproof chamber. Data stored on microcassettes were off-loaded

weekly onto diskettes for storage and later analysis on a laboratory PC.

V. Results

Initial surveys

From August through October 1985, six water lettuce sites were identified and surveyed for *Mansonia* with the goal of choosing two for longer-term comparisons. Emergence trapping, examination of fauna attached to *Pistia* roots, and egg mass surveys were used to assess *Mansonia* abundances at the six localities. Traps at one site were vandalized, and another locality produced no *Mansonia*, so these two were removed from further consideration. From the remaining four, an abandoned aquaculture pond at Chinese Farm (CF) was selected as a highly productive *Mansonia* site. A protected drainage canal on Highway 614 (HWY 614) produced approximately ten-fold fewer *Mansonia* adults even though egg mass densities were similar to CF. These latter two sites were used exclusively for the remainder of studies.

Pistia growth and die-off

Monthly measures of *Pistia* productivity began in November at CF and January at HWY 614. Cold temperatures in January produced a precipitous drop in leaf and root biomass at CF (Fig. 1a). Leaf and root biomass remained low during winter and spring; leaf biomass finally showed an upturn in June. Biomass values at HWY 614 were consistently lower than at CF (Fig. 1b). (No quadrat samples were taken from HWY 614 in June.)

Pistia leaf areas showed similar seasonal trends, dropping from 3000 to less than 1000 square cm per quadrat after January cold at CF; an increase in leaf area was not recorded until June (Fig. 2). *Pistia* biomass values were consistently lower at HWY 614 than at CF.

Interestingly, mean numbers of *Pistia* plants and leaves did not follow the seasonal patterns of biomass and leaf area (Fig. 3a). When large plants were killed by January cold, new plants with small leaves were produced vegetatively. Thus, the number of plants and leaves in March exceeded that in November (Fig. 3a), although biomass and leaf area values were much reduced in March (cf. Figs. 1a, 2). The numbers of flowers per quadrat remained fairly constant at CF except for an unexplained decline in June. Mean numbers of plants and flowers at HWY 614 did not show a prominent increase in March, and flowers were never observed at this site (Fig. 3b).

Invertebrates from roots

Older larval stages of *Mansonia* predominated in quadrat samples from November through January, and first instars and pupae were rare (Fig. 4). Larval densities remained high in

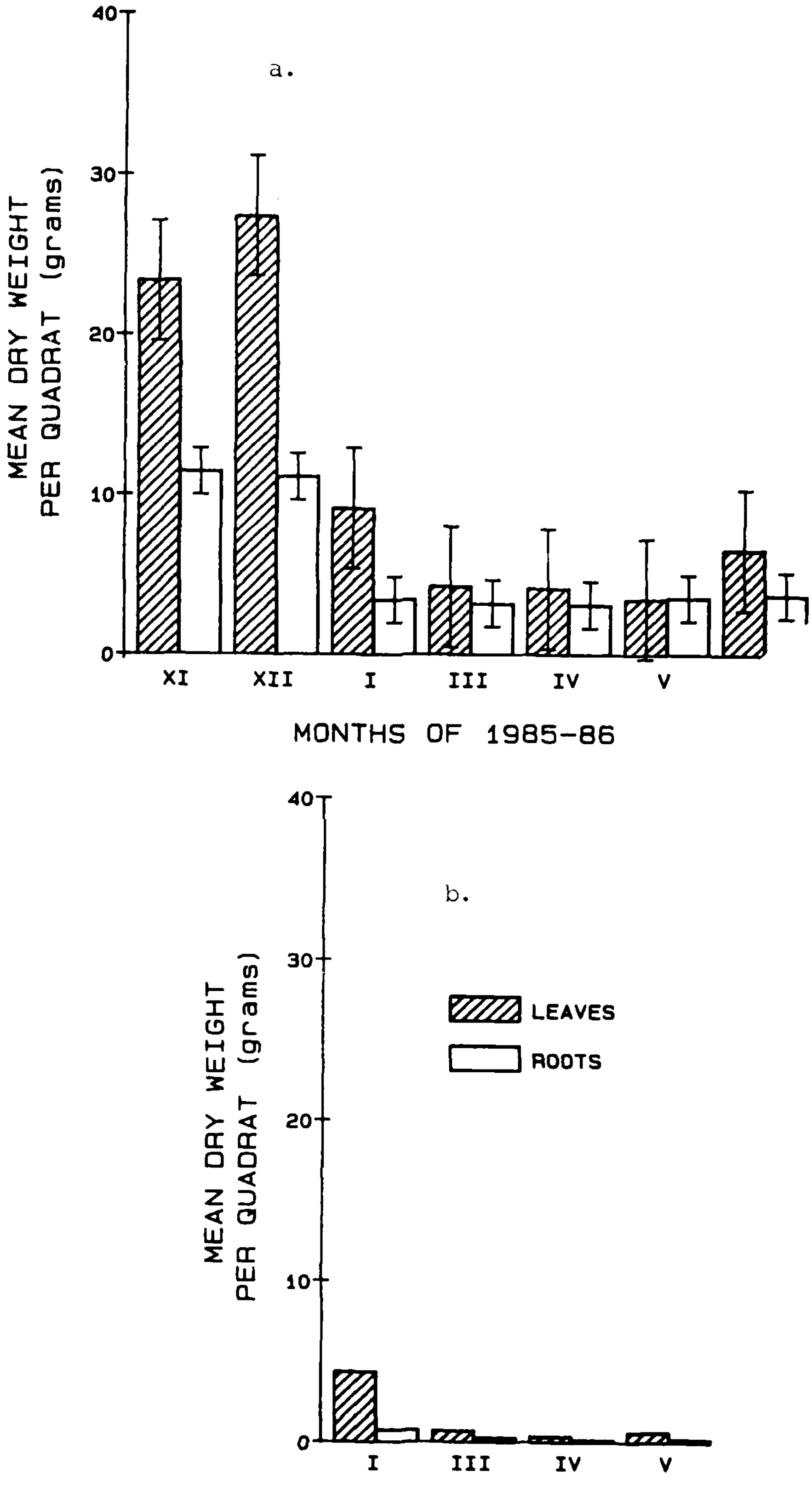


Fig. 1. Mean dry weights of water lettuce leaves and roots from five quadrat samples taken at approximately monthly intervals from (a) Chinese Farm and (b) HWY 614. Sampling at HWY 614 did not begin until January and no data were collected there in June 1986. Error bars represent + 1 SE.

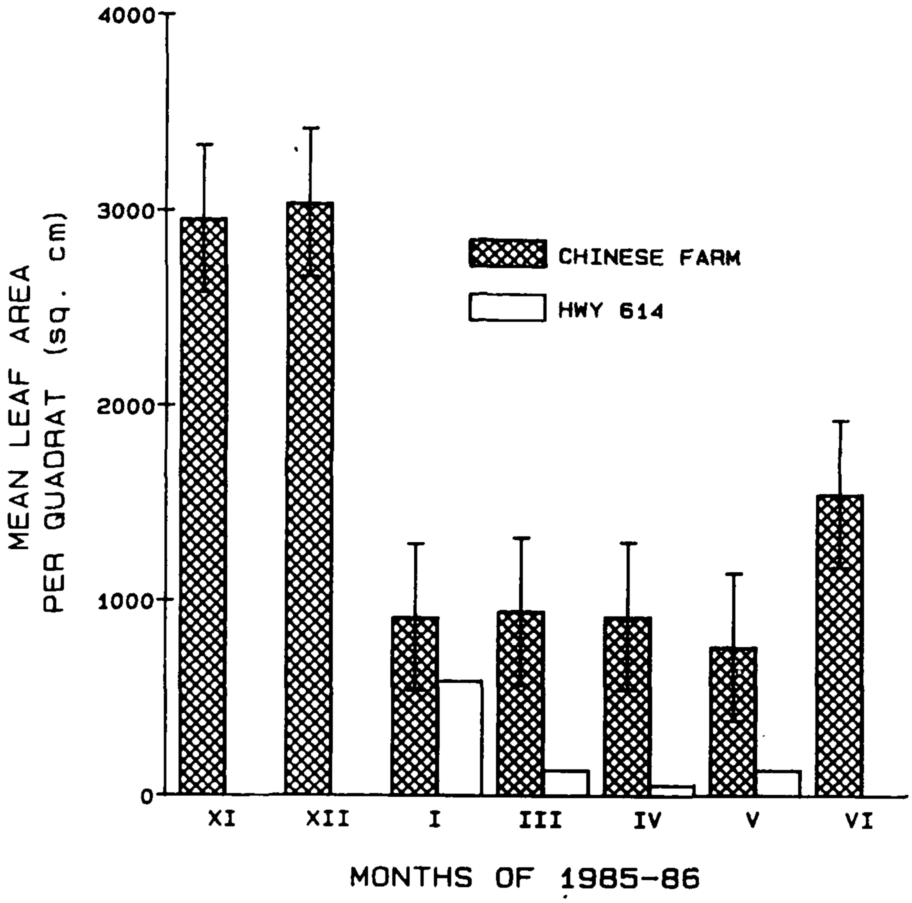


Fig. 2. Mean leaf areas from five quadrat samples at CF and HWY 614. HWY 614 was not sampled in November, December, or June. Error bars represent ± 1 SE.

January samples even though root biomass had decreased (Fig. 1a), suggesting that the cold temperatures did not kill larvae. However, larval densities were depressed from March through June at CF. No larvae were collected at HWY 614 during four winter and spring quadrat samples.

Mean numbers of the most abundant aquatic invertebrate groups other than Mansonia in quadrat samples are indicated in Tables 1 and 2. At CF, odonate larvae were the most abundant aquatic insects, followed by Hemiptera and Coleoptera. Most taxa were less abundant at HWY 614, except for Mollusca and Ephemeroptera. A list of the taxonomic classifications of organisms is provided in Appendix II.

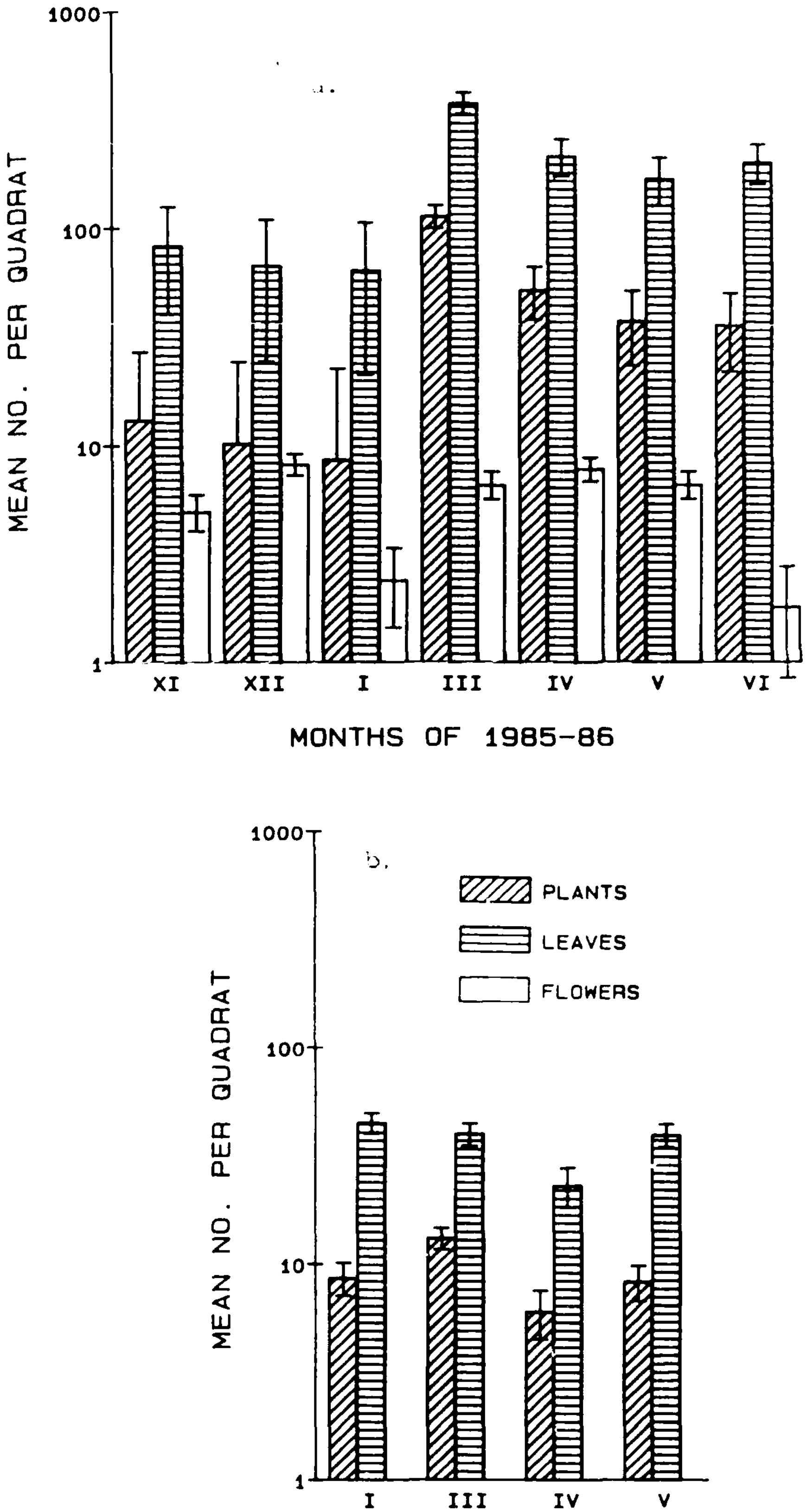


Fig. 3. Mean numbers of plants, leaves, and flowers from five quadrat samples at (a.) CF and (b.) HWY 614. No *Pistia* flowers were recorded from HWY 614. Error bars represent + 1 SE.

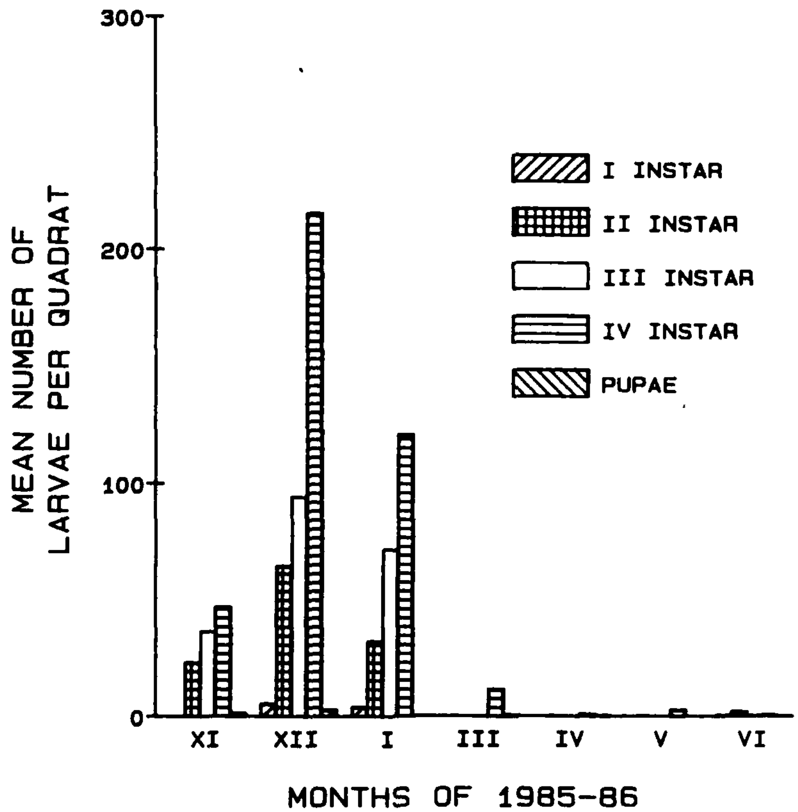


Fig. 4. Mean numbers of Mansonia larvae, by instar, from five monthly quadrat samples at Chinese Farm. No data were collected in Febraury.

Table I. Mean numbers per quadrat of invertebrates other than Mansonia from CF.

Sample Date:	20/XI/85	17/XII/85	13-15/I/86	12/III/86	16/IV/86	21/V/86	25/VI/86
n	5	3	5	5	5	5	5
Other Culicidae	0.60	4.33	8.80	0.80	0.00	1.00	0.60
Other Diptera	2.00	19.33	28.80	22.40	22.00	22.20	15.20
Annelida	4.20	28.00	52.00	44.60	9.00	7.80	18.40
Mollusca	15.80	5.33	6.00	7.00	18.00	94.80	11.00
Ephemeroptera	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Odonata	84.00	88.00	129.80	108.40	38.60	34.20	26.80
Hemiptera	36.80	41.33	24.20	26.40	37.80	45.80	60.60
Coleoptera	10.00	16.67	20.00	22.00	16.60	19.60	32.40
Lepidoptera	0.00	0.33	0.00	0.20	0.00	0.80	3.20

Table II. Mean numbers per quadrat of invertebrates other than Mansonia from HWY 614.

Sample Date:	20-22/I/86	19/III/86	23/IV/86	28/V/86
n	5	5	4	5
Other Culicidae	0.20	0.00	0.00	0.20
Other Diptera	0.80	1.20	2.75	14.00
Annelida	8.40	1.00	2.00	2.20
Mollusca	2.40	24.40	72.00	207.80
Ephemeroptera	0.00	0.00	0.75	17.00
Odonata	23.80	11.60	16.00	50.00
Hemiptera	1.60	1.40	1.75	13.60
Coleoptera	22.40	18.60	22.00	20.40
Lepidoptera	0.20	1.00	0.00	0.40

Aerial insects in emergence traps

Mansonia emergence declined gradually from September to November with a small increase in November at both sites (Fig. 5). Densities of *Mansonia* adults remained consistently *ca* ten-fold higher at CF than at HWY 614 from September through December. At both sites, emergence stopped altogether in January and only two *Mansonia* adults were captured from January through June.

Among other aerial insects captured, Chironomidae and Ceratopogonidae predominated. A taxonomic list of insects identified from emergence traps is contained in Appendix III.

Seasonality of oviposition

The mean numbers of eggs per leaf were similar at CF and HWY 614 during September and October (Fig. 6). In November, oviposition activity increased at CF but decreased at HWY 614; only a single egg mass was found at the latter site after late November. Egg laying declined at CF in December and ceased in January. Only a few new egg masses were recovered between February and June.

Water chemistry

Dissolved oxygen was substantially higher at CF (mean = 2.39 ppm $\pm$ 0.50 SE, n = 7) than at HWY 614 (mean = 0.89 ppm $\pm$ 0.19 SE, n = 6) during monthly sampling; pH was slightly greater at CF (mean = 7.17 $\pm$ 0.07 SE, n = 7) than at HWY 614 (mean = 6.92 $\pm$ 0.11 SE, n = 6).

At both sites, nitrites and nitrates were below detectable limits on most all sampling dates (Fig. 7). Ammonia levels were similar at the two sites, but the average values of total phosphates were *ca* 15 times greater at CF than HWY 614.

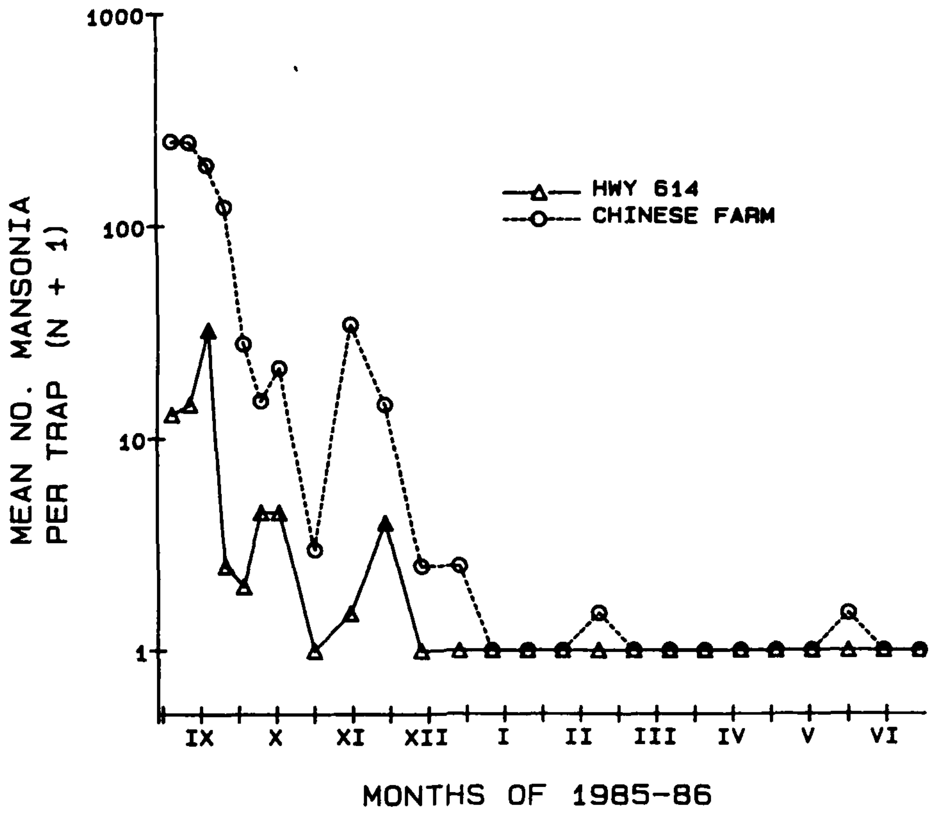


Fig. 5. Mean numbers of adult Mansonia captured in weekly exposures of two emergence traps at Chinese Farm and HWY 614. Traps were exposed during alternate weeks beginning in November 1985.

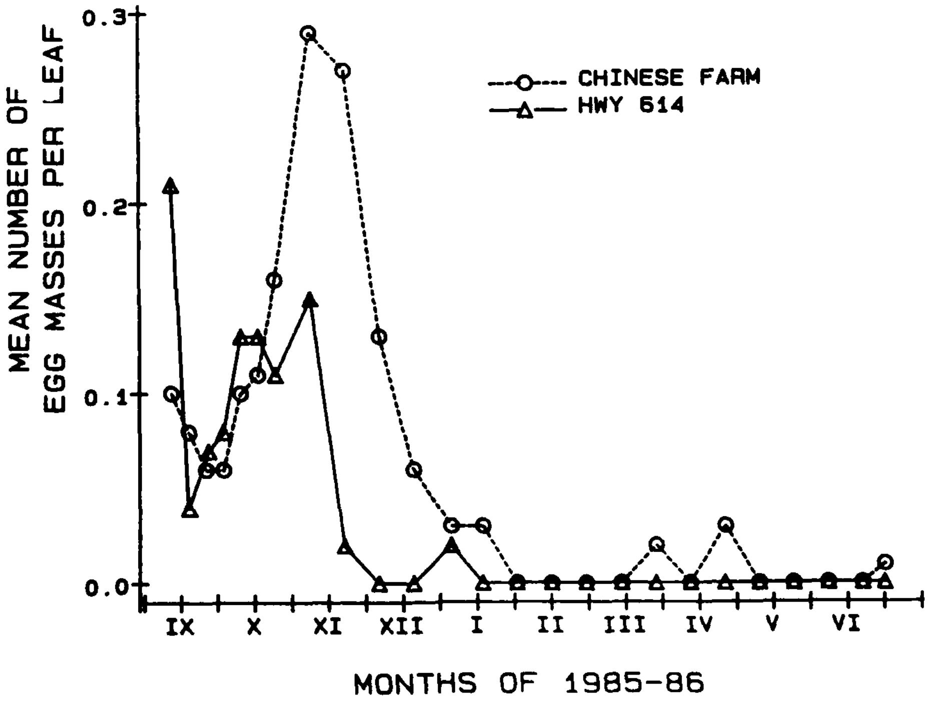


Fig. 6. Mean numbers of Mansonia egg masses per Pistia leaf. Fifty to 100 leaves greater than 10 cm in length were sampled per observation except in the winter and spring when such lengths were not available.

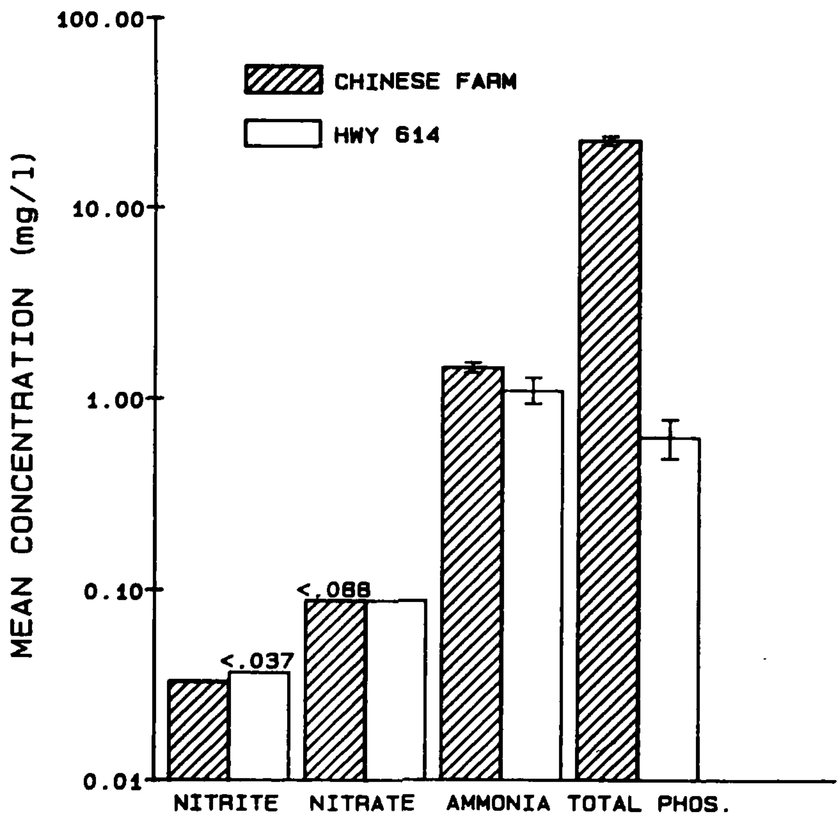


Fig. 7. Average water chemistry values for monthly measurements beginning in December 1985 at CF and January 1986 at HWY 614. Nitrites and nitrates were usually below the limits of detection of the test kit.

Egg mass position

Among 207 viable *Mansonia* egg masses recovered from *Pistia* leaves during censuses, 73 (35.3%) were on the under surfaces. The location of each mass on an average-sized leaf is depicted in Fig. 8. All masses were within 0.25 cm of the leaf edge except for four, these apparently laid through holes caused by insect damage. All under-surface oviposition is apparently executed with the female secured by mid- and hind legs to the upper surface and bending her abdomen to reach the underside.

The remaining 134 egg masses (64.7%) were found on upper leaf surfaces. Prior to this report, only anecdotal information had ever documented upper-surface oviposition by *Mansonia*. These masses were usually located near water line, but were evenly distributed across the breadth of an average leaf (Fig. 9). Clearly, the *Mansonia* female must use a different behavior to execute upper-surface oviposition. Many egg masses were recovered well out of water, which would strand larvae hatching in this location. Preliminary experiments and observations suggest that leaves may droop or plants sink into the water during the 7-8 day incubation period of eggs.

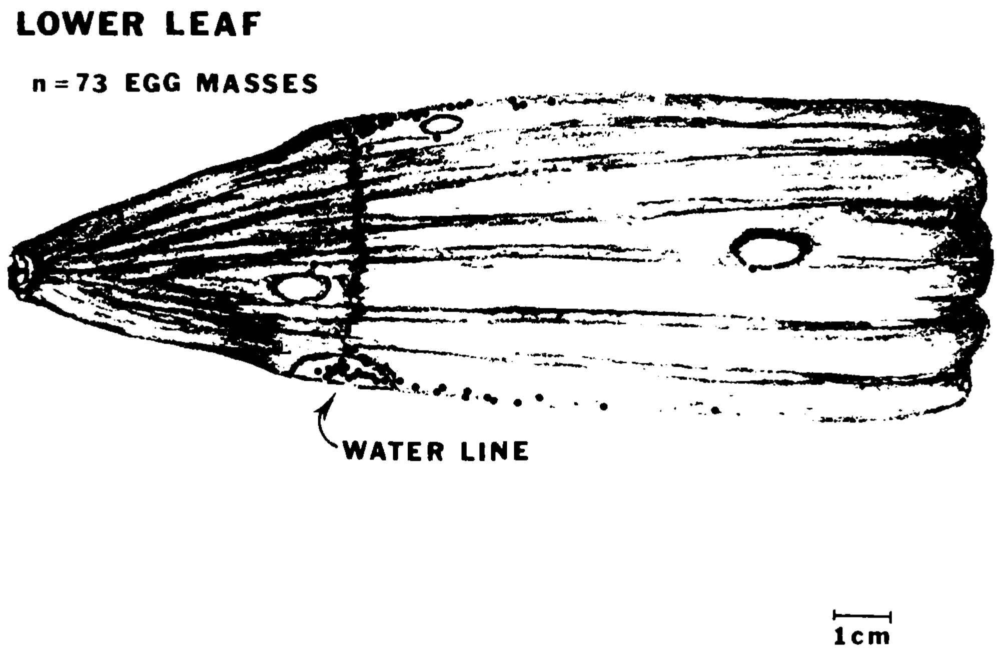


Fig. 8. The distribution of <u>Mansonia</u> egg masses on the under surfaces of 3257 <u>Pistia</u> leaves sampled between September 1985 and January 1986. Masses more than 0.3 cm away from the leaf edge were laid through holes due to insect damage.

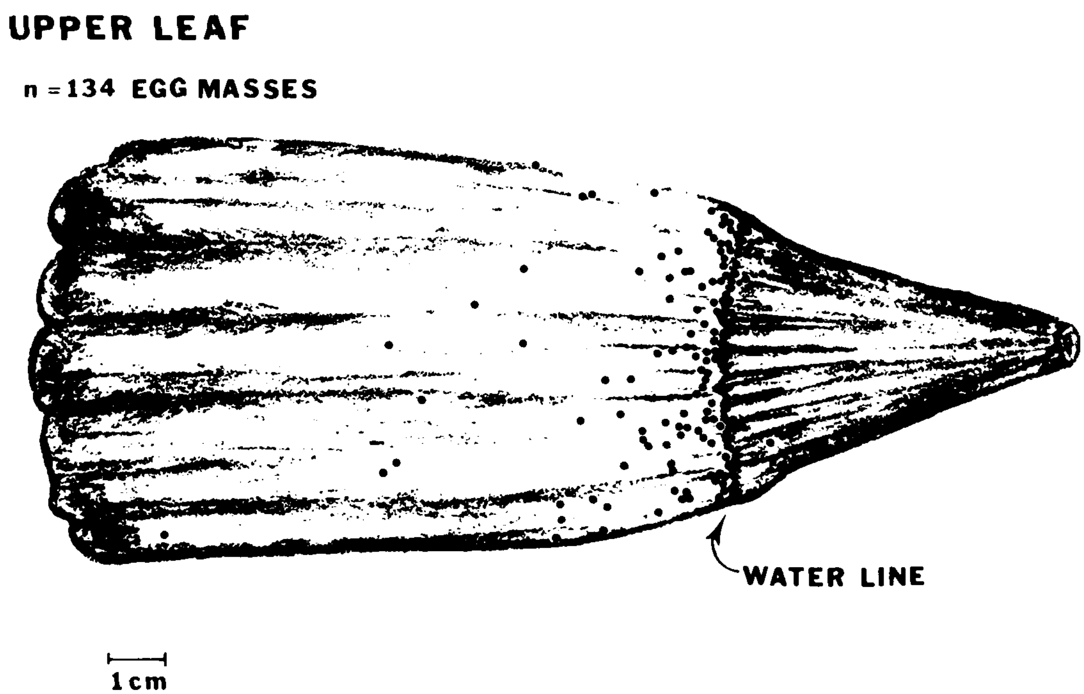


Fig. 9. The distribution of <u>Mansonia</u> egg masses on the upper surfaces of 3257 <u>Pistia</u> leaves sampled between Sept. 1985 and January 1986.

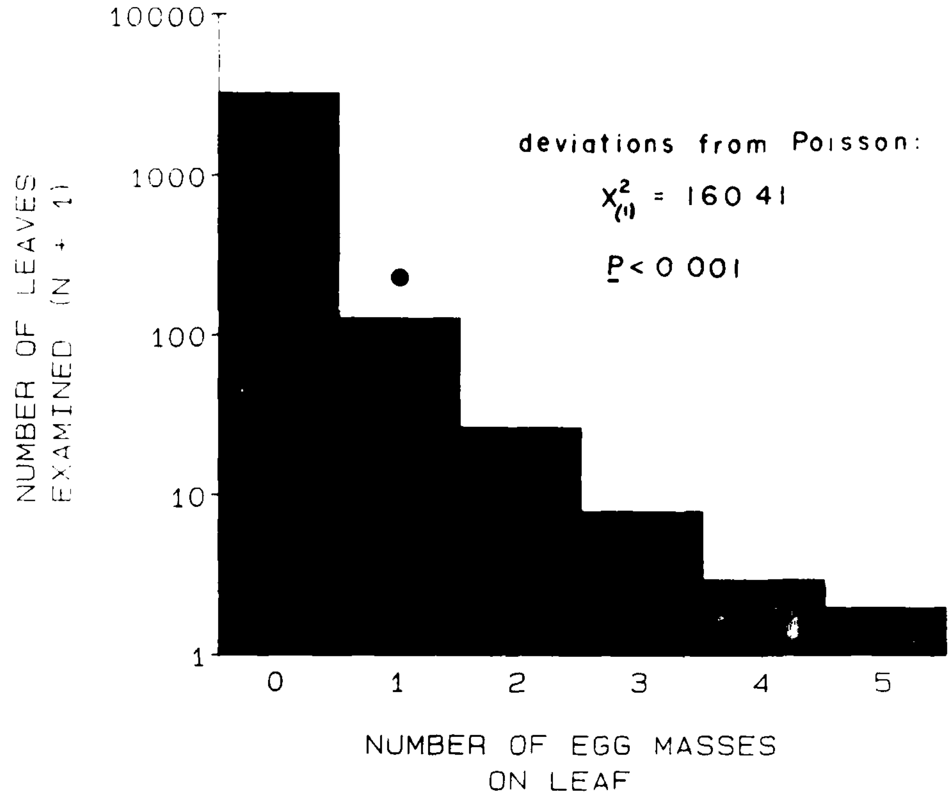


Fig. 10. The frequency distribution of egg masses on 3257 Pistia leaves. Black dots show expected values based on a Poisson distribution, and the chi-squared value measures the deviation of observed frequencies from a Poisson.

Since 95 % of the Mansonia captured from Pistia are M. dyari, we expected that this species was responsible for both the upper and lower surface oviposition. To confirm this, female Mansonia were collected with bait traps, allowed to blood-feed, and separated by species. Gravid females of M. dyari were exposed overnight in a large cage to a tray of whole Pistia plants. Thirty-two of 46 egg masses laid (69.6%) by M. dyari were on upper surfaces, the remainder on under surfaces. By contrast, all ovipositions (n = 9) of M. titillans, tested in a separate cage, occurred on lower leaf surfaces.

The frequency distribution of number of eggs per leaf was examined for the 3257 leaves censused in nature. As many as five viable egg masses were recovered from single leaves (Fig. 10). The distribution of egg masses on leaves deviated significantly from a normal (Poisson) distribution due to overdispersion, i.e., the data indicate that egg masses are aggregated on leaves.

Predation on Mansonia larvae

Late in January, 10 Anisoptera and 10 Zygoptera larvae were captured at CF and their foreguts dissected. Remains of Mansonia larvae were detected in 30% of the Anispotera and 10 (possibly 20) % of the Zygoptera. Sampling and dissections were repeated 2 days later at CF and these revealed that 1 of 7 Zygoptera and 1 of 7 Anispotera contained mosquito remains. Subsequent efforts to conduct controlled experiments on predation have been inconclusive because of the dearth of Mansonia in nature during 1986.

VI. Discussion and Conclusions

Data acquired early in this study confirmed that Mansonia levels varied widely among habitats that appear superficially suitable. Our intensive study of two sites, CF and HWY 614, was begun too late in the Mansonia season to ascertain reasons for the different levels of mosquito abundance at the two sites. Nevertheless, important data were acquired bearing on the Pistia-Mansonia relationship.

Cold weather reduced both Pistia and Mansonia populations. Mansonia oviposition declined (Fig.6) even before the major Pistia die-off attributable to January freezes. Mansonia larvae remained abundant even as host plants died in January, but by winter's end larvae were scarce (Fig. 4). Since there was virtually no winter emergence of adults (Fig. 5), we must assume that larvae suffered high mortality in the winter. The rarity of Mansonia into June suggested that the cold-induced population depression is severe, and rebound to pre-winter levels requires considerable time.

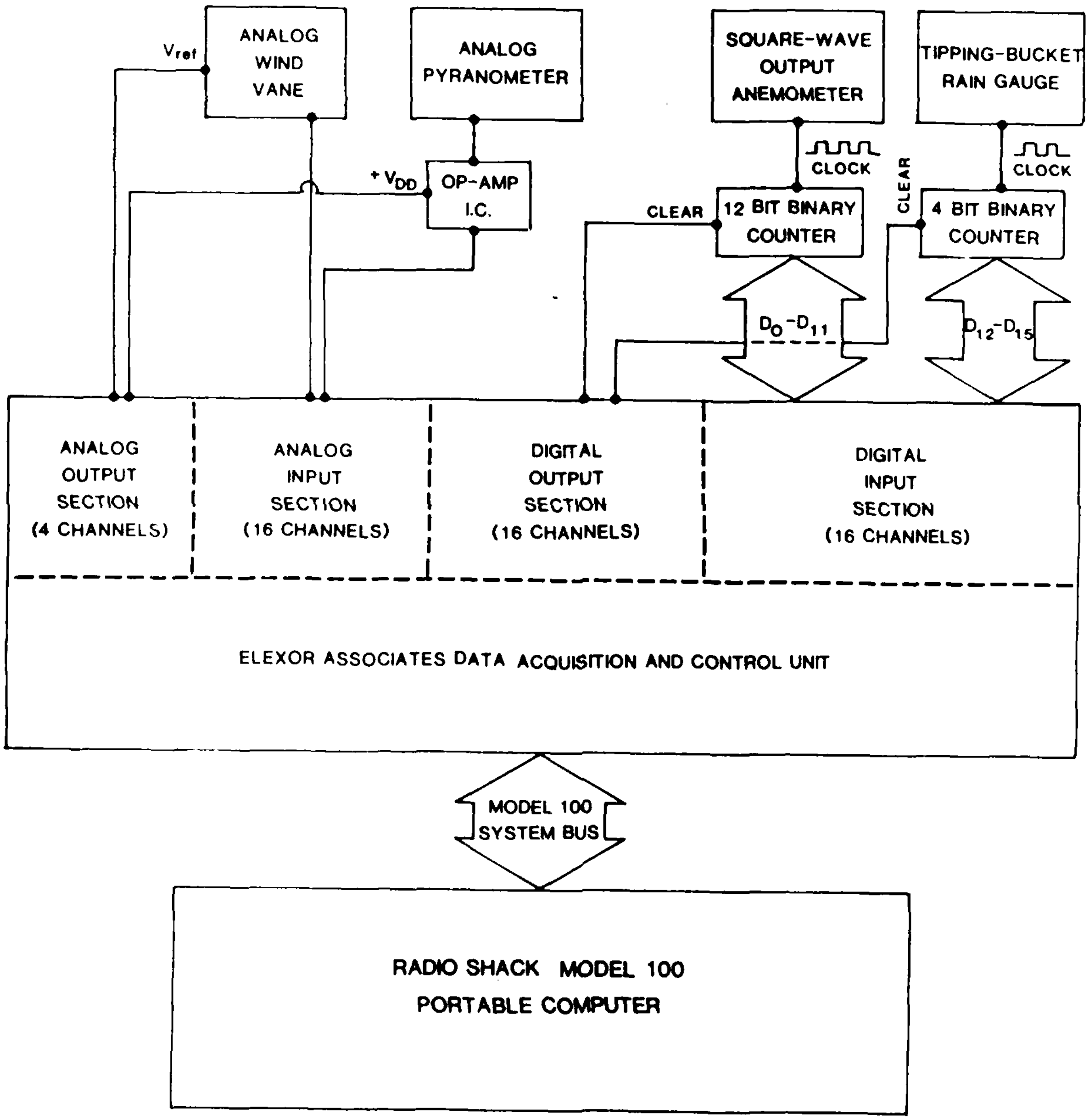
More information is necessary to determine whether such factors as water chemistry or predation limit Mansonia populations. The persistently low level of nitrates at both CF and HWY 614 may suggest some nitrogen limitations affecting larval growth. If odonate larvae regularly prey on Mansonia, this group of predators, through their sheer abundance (Tables 1 & 2) may regulate Mansonia populations.

The capacity of M. dyari, and not M. titillans, to lay on both the upper and under sides of Pistia leaves, apparently represents an evolutionary specialization of the former species for water lettuce. Unlike many floating macrophytes, Pistia leaves usually do not rest flat on the water surface, limiting the opportunities for under-surface oviposition 'typical' of Mansonia. The ability of M. dyari to use upper leaf surfaces of Pistia which will sink into the water by the time of hatching represents a specialized adaptation to this host plant.

Because of the unexpectedly slow recovery of Mansonia populations in 1986, much of the experimental work must be deferred until year 2 of this project.

Appendix I.

BLOCK DIAGRAM
OF
ENVIRONMENTAL DATA-LOGGING SYSTEM



Appendix II. List of invertebrates and fish captured in quadrat samples at CF and HWY 614. Where genus and species are not given, identification was made only to family level.

Mollusca
- Gastropoda
  - Pulmonata
    - Lymnaeidae
      - *Lymnaea* sp.
- Pelecypoda
  - Family unknown

Platyhelminthes
- Turbellaria
  - Tricladida
    - Planariidae

Annelida
- Oligochaeta
  - Family unknown
- Hirundinea
  - Rhynchobdellida
    - Glossiphoniidae
      - *Placobdella rugosa*

Arthropoda
- Crustacea
  - Ostracoda
    - Family unknown
  - Copepoda
    - Family unknown
  - Amphipoda
    - Talitridae
      - *Hyalella azteca*
  - Decapoda
    - Family unknown
- Insecta
  - Diptera
    - Culicidae
      - *Mansonia dyari*
      - *Mansonia titillans*
      - *Culex erraticus*
      - *Culex* sp.
      - *Anopheles* sp.
      - *Uranotaenia* sp.
    - Chaoboridae

Diptera (continued)
- Ceratopogonidae
- Chironomidae
- Stratiomyiidae
- Tabanidae

Ephemeroptera
- Caenidae
  - *Caenis* sp.

Odonata
- Libellulidae
  - *Pachydiplax longipennis*
  - *Miathyria murcella*
  - *Erythemis simplicollis*
- Aeshnidae
  - *Coryphaeschna adnexa*
- Agrionidae
  - *Telebasis byersi*
  - *Ischnura posita*
  - *Ischnura rambui*

Hemiptera
- Pleidae
  - *Plea* sp.
- Naucoridae
  - *Pelocoris* sp.
- Belostomatidae
  - *Belostoma* sp.
  - *Lethocerus* sp.

Coleoptera
- Haliplidae
  - *Peltodytes* sp.
- Dytiscidae
  - *Celinni slossoni*
- Hydrophilidae
  - *Neohydrophilus costus*
- Helodidae
- Noteridae
  - *Hydrocanthus oblongus*
  - *Suphisellus* sp.
- Carabidae

Neuroptera
- Sialidae

Lepidoptera
- Tineidae
  - *Acrolophus* sp.
- Pyralidae
  - *Samea* sp.

Arachnida
- Acarina
  - Family unknown

Vertebrata
- Osteichthyes
  - Atheriniformes
    - Poeciliidae
      - *Gambusia affinis*
      - *Heternadria formosa*

Appendix II. List of invertebrates and fish captured in quadrat samples at CF and HWY 614. Where genus and species are not given, identification was made only to family level.

- Mollusca
  - Gastropoda
    - Pulmonata
      - Lymnaeidae
        - *Lymnaea* sp.
  - Pelecypoda
    - Family unknown
- Platyhelminthes
  - Turbellaria
    - Tricladida
      - Planariidae
- Annelida
  - Oligochaeta
    - Family unknown
  - Hirundinea
    - Rhynchobdellida
      - Glossiphoniidae
        - *Placobdella rugosa*
- Arthropoda
  - Crustacea
    - Ostracoda
      - Family unknown
    - Copepoda
      - Family unknown
    - Amphipoda
      - Talitridae
        - *Hyalella azteca*
    - Decapoda
      - Family unknown
  - Insecta
    - Diptera
      - Culicidae
        - *Mansonia dyari*
        - *Mansonia titillans*
        - *Culex erraticus*
        - *Culex* sp.
        - *Anopheles* sp.
        - *Uranotaenia* sp.
      - Chaoboridae

- Diptera (continued)
  - Ceratopogonidae
  - Chironomidae
  - Stratiomyiidae
  - Tabanidae
- Ephemeroptera
  - Caenidae
    - *Caenis* sp.
- Odonata
  - Libellulidae
    - *Pachydiplax longipennis*
    - *Miathyria murcella*
    - *Erythemis simplicollis*
  - Aeshnidae
    - *Coryphaeschna adnexa*
  - Agrionidae
    - *Telebasis byersi*
    - *Ischnura posita*
    - *Ischnura rambui*
- Hemiptera
  - Pleidae
    - *Plea* sp.
  - Naucoridae
    - *Pelocoris* sp.
  - Belostomatidae
    - *Belostoma* sp.
    - *Lethocerus* sp.
- Coleoptera
  - Haliplidae
    - *Peltodytes* sp.
  - Dytiscidae
    - *Celinni slossoni*
  - Hydrophilidae
    - *Neohydrophilus costus*
  - Helodidae
  - Noteridae
    - *Hydrocanthus oblongus*
    - *Suphisellus* sp.
  - Carabidae
- Neuroptera
  - Sialidae

- Lepidoptera
  - Tineidae
    - *Acrolophus* sp.
  - Pyralidae
    - *Samea* sp.
- Arachnida
  - Acarina
    - Family unknown
- Vertebrata
  - Osteichthyes
    - Atheriniformes
      - Poeciliidae
        - *Gambusia affinis*
        - *Heternadria formosa*

Appendix III. List of insects captured in emergence traps at CF and HWY 614. Where identifications are given only at the family level, genus and species determinations are not yet available.

- Diptera
  - Culicidae
    - *Culex erraticus*
    - *Mansonia dyari*
    - *Mansonia titillans*
    - *Anopheles crucians*
    - *Anopheles quadrimaculatus*
    - *Uranotaenia lowii*
    - *Uranotaenia sapphirina*
    - *Culex nigripalus*
  - Ceratopogonidae
    - *Bezzia* sp.
    - *Culicoides insignis*
    - *Dasyhela* sp.
    - *Forcipomyia* sp.
    - *Stilobezzia bulla*
    - *Stilobezzia sybleae*
  - Chironomidae
    - *Chironomus decorus*
    - *Cladopelma* sp.
    - *Goeldichironomus holoprasinus*
    - *Monopelopia boliekae*
    - *Parachironomus directus*
    - *Polypedilum trigonus*
    - *Tanypus punctipennis*
    - *Tanytarsus* sp.
    - *Zavrelimyia* sp.
  - Sciaridae
    - *Bradsia* sp.
  - Chaoboridae
    - *Chaoborus* sp.
  - Stratiomyiidae
    - *Hedriodiscus trivittatus*
  - Psychodidae
    - *Psychoda* sp.
  - Syrphidae
  - Agromyzidae
  - Cecidomyidae
  - Chloropidae
  - Dolichopodidae

- Diptera (continued)
  - Ephydridae
  - Phoridae
  - Tachinidae
  - Tipulidae
- Lepidoptera
  - Pyralidae
    - *Samea multiplicalis*
- Homoptera
  - Cicadellidae
    - *Empoasca* sp.
  - Aleyrodidae
    - *Trialeurodes abutilonea*
  - Aphididae
- Thysanoptera
  - Phlaeothripidae
    - *Hoplothrips flavicauda*
- Hymenoptera
  - Eulophidae
    - *Tetrasticus* sp.
  - Braconidae
  - Diapriidae
  - Formicidae
  - Trichogrammatidae
- Ephemeroptera
  - Caenidae
    - *Caenis* sp.
- Coleoptera
  - Noteridae
  - Dytiscidae
  - Staphylinidae
- Odonata
  - Libellulidae
    - *Erythemis simplicollis*
    - *Erythemis attala*
  - Agrionidae
    - *Telebasis byersi*

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